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ABSTRACT

In view of the changing relationship between science, technology, and the quality of life, future efforts need to be devoted to the use of new knowledge for social objectives rather than for economics and defense. The mass of problems facing society today, which to some extent are direct side effects of technological growth, appear to have three interactive and inextricable causes: (1) the increase in world population and accumulation of population in urban areas, (2) an increase in level of affluence, and (3) the unmanaged upsurge of technology which has been the agent for producing affluence and urbanization. These problems appear to have three features in common. They are global and seem to appear in any kind of society at a certain level of development irrespective of the social or political system. Second, they are extremely complex and multi-variant in economic, social, political, and psychological aspects that are difficult to disentangle. Third, they are enormously interactive. Pessimistic projections from the world model developed at Massachusetts Institute of Technology (MIT) are not merely an experiment in futurology; they are an analysis of trends that indicate what is likely to happen if present growth and policy persist. The human species approaches a moment of findamental crisis. There are ways out, but little time is left to initiate the basic changes in human objectives, motivation, and behavior that are necessary if man is to survive. (LH)

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Science, Technology and the Quality of Life

Dr. Alexander King

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INSTITUTE FOR CULTURAL RESEARCH

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SCIENCE, TECHNOLOGY AND THE QUALITY OF LIFE

Based upon a lecture given under the aegis of the
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One of the Institute's objectives is to encourage multi-disciplinary and inter-disciplinary thought. It seemed to me, therefore, that among the many other topics which appear in the Institute's list of lectures, it would be useful to have a talk about the present state of science in the world. What I shall be discussing tonight is essentially inter-disciplinary; my basic theme is the need to regain the unity of science and of knowledge in order to apply them coherently to the understanding of our world and also to reject a purely linear type of thinking.

I have chosen the title rather carefully—three linked subjects—science, technology and the quality of life. All three are conceptually rather ambiguous topics, and are interpreted in very different ways by different people. I want to talk first of all about each one of them separately, not in a specifically semantic sense but rather more generally.

It is rather difficult for one who has worked elsewhere to talk about science to an audience in England or America, because the English-speaking countries are ridden with the Anglo-Saxon heresy that science is confined to subjects such as chemistry, physics, engineering and so on, whereas in nearly all other countries in the world—in the Latin countries certainly, in the Soviet Union, in China, in Japan, the term science is equivalent to the word knowledge, *connaissance,Nauk, Wissenschaft*. Hence attitudes to science are very different in different countries. One has heard a good deal here in the last twenty years of the so-called two cultures promulgated by C.P. Snow and about the difficulties of the relations between the sciences (in the English sense) and the humanities. Other people look at it a little differently; for instance, Margaret Meade, the anthropologist, regards C.P. Snow's concern with the separation of the two cultures as a mere matter concerning the elite of a small part of the English-speaking world. Consequently, I want you tonight to regard science in the broader sense, not necessarily including the whole spectrum of the humanities and speculative thought, but essentially as an orderly and systematic approach to man's knowledge of the physical laws, of himself, his environment, and his society. This approach is generally made, according to the present scientific method, by investigation, by probing, by experiment, by putting forward hypotheses and trying to test them. This of course is basically a cerebral approach, it is basically mental. However, it is by no means entirely so and not nearly as mental I think as it purports to be or as scientists generally imagine it to be. Most really great scientific discoveries are I think to a very large extent intuitive, but based on an enormous extent of accumulated knowledge and rational experience. There are, of course, innumerable pedestrian scientists, as there are pedestrian people in other fields, who have very little intuitive or creative contribution to make. But from my experience in the natural sciences, the creative process in research is not all that different from the creative process, shall we say, in music or in writing poetry. Once the flash of creativity has been achieved, there is generally a *post facto* rationalisation. In most important scientific discoveries, probing into the unknown, three or four initial approaches or hypotheses may present themselves. Each of these may lead to a host of alternatives at the next step and the whole process rapidly fans out. In the creative process an intuitive jump may suggest the point of break-through without a laborious explanation of the innumerable alternatives.

Of course once the jump has been made to a new discovery, then it is quite possible and quite legitimate, and certainly very traditional to work back from the discovery and indicate the whole thing as a rational process.

It is also true, particularly in mathematical sciences, that most *great* discoveries—the creative phase of a man's work—come rather early in his career; creative discovery in a young man's job, in fact fundamental scientific research, undertaken in the University is to a very large extent successful because it provides a symbiosis of the experience of a good professor who has possibly passed his most creative phase, with the new, intuitive and creative attitude of whole cohorts of younger research people. These younger, less experienced, workers come up with ideas, which although often naive are creatively suggestive; they cross-fertilize with the experience and information of the older professor and lead to completely new things, thus maintaining a vitality which may persist into the old age of a first-class professor.

In the nature of things and as the sciences are at present classified and institutionalised, we are still following the system which was established by the foremost German scientists of the 19th century, at the time of Liebig and Bunsen. At that time the natural sciences were developing separately and could be nicely classified into little boxes marked "chemistry", "physics", "geology", and so on. This was very convenient, very effective, and has worked well until fairly recently. In the social sciences which developed later, classification is much less clear. Very often classification is a matter of mere convenience and orientation, and varies from country to country. The differences between sociology, social anthropology and social psychology, for instance, are to some extent different ways of looking at particular phenomena, and can all too easily lead to a rabid sectarianism.

It seems to us now, however, that the growth of the sciences, particularly the natural sciences, has reached a stage when they can no longer be looked at separately. First of all, inter-face sciences began to develop between subjects such as chemistry and biology, for example, bio-chemistry, and later on more complicated linkages appeared in the form of subjects such as molecular biology. As developments take place, these new subjects themselves interact with one another, in a kind of dynamic development of knowledge. Where subjects of concern and interest of the moment are, if you like, temporary subjects, it is hardly necessary even to give them a name or regiment them into a class; for they themselves, as the frontiers of knowledge are pushed back, will tend to react with other such subjects. I am at the moment associated with an attempt to look at one or two particularly difficult multi-disciplinary fields in science, to see how they can be cultivated. We are considering, for example, the topic of brain and behaviour, a subject where the participating disciplines include subjects such as bio-chemistry, neurology, neuro-physiology, molecular biology, psychology, psychiatry and so on. To get people of such disciplines working together is enormously difficult, and probably enormously important, for some of these new subjects. But again, this field will advance; its name will change, its emphasis will change. I put it to you therefore that in the advancement of knowledge we require a much more kinetic kind of approach to the development of science, rather than the static, classified, approach of the past, which has led to compartmentalization, to extreme specialization and to a retreat from the realities of life in some cases. Certainly it has made it difficult to perceive the connections and appreciate the unity of knowledge the unity of all existence in which knowledge has a place. The same phenomenon is now beginning to appear more and more with the subjects to which science and technology are applied. Nearly all the problems facing society today cannot be attacked by single disciplines. They have economic, social, technical, natural science and social science facets, and their approach by one of these alone seldom leads to valid solutions. The present static classifications of the sciences which I have described, and the undisciplinary and linear way of attacking problems is reflected also in our institutions—university faculties and government departments which have become essentially obsolete.

Now as to technology: technology has become increasingly in the last few years a dirty word. It is the agency through which knowledge is productively applied, and it is generally thought of in terms of engineering, although the new so-called "software" technologies are appearing, first in computers and now in many other fields. Of course technology is a very old subject; in a sense we are all children of technology. In the early days of man, the discovery of fire and its use, the lever, the wheel, the simple metallurgical arts, agriculture, all these were technological advances; very necessary for lifting man from his initial state of having to spend all his time in seeking shelter and food. The rise from the subsistence level required, and was made possible by, these simple technologies which developed very slowly and gradually as centuries went by.

The present revulsion against technology to my mind is not really against technology as such but against the misuse of technology; it arises from our complete lack of mastery over technology, and over so-called technological progress. The condemnation of technology is mainly due to its abuse and mis-management rather than its inherent nature, and is very often concerned with institutions which have been built up or which have appeared in order to develop and exploit technology, the kind of thing that Eisenhower talked about as the military industrial complex, etc.

The third topic: quality of life. This again is very ambiguous, and means different things to different people. At an early stage in man's development, when he is subsisting at a low level, the

only really valid form of quality seems to be economic; he has to produce some resources, some accumulation of capital, otherwise he is living like the cow, eating grass all the time in order to live, without any leisure, possibility of developing, and so forth. As wealth accumulates, questions come in, particularly in relation to technology, as to whether the material goals of society are sufficient. At present there is a general feeling that quality is slipping away, is leaking from life, and that we do not know what value is any more. Obviously, one's concept of the quality of life, depends entirely on the individual's ideas and beliefs in relation to the value system on which his life, his society, operates. At present these values, at any rate in a mass sense, are mainly material. Science and technology should– and to a large extent do–respond to the value system of society, and up till now they have responded, as one would expect, to value systems which were essentially material.

Now the connection between these three topics science, technology, the quality of life, one might call briefly science policy, if that is interpreted widely enough to mean the mastery of technical progress, or still more widely to include the question as to how society and the individual can make the maximum use of knowledge. Of course this is extremely difficult to achieve, even in the most simple materialistic sense. Governments concerned with science policy, with the attempt to master technology for national aims, find it very difficult to look at the various individual parts of the question, and to bring them together. As I said once in a speech made at Dallas, Texas, science policy is well nigh impossible, owing to the naivete of the natural scientists, the arrogance of the economists, the bloody-mindedness of the bureaucrats and the ignorance of the politicians. And all these different qualities coincide and reinforce one another, in earnest confusion; the conjunction of separate unidisciplinary approaches does not in itself provide for a coherent multidisciplinarity.

Now let me say a word or two about the rise of the natural sciences, which has been so spectacular in the last few decades. The amount of resources used for research and development has grown exponentially for about 200 years. For a long time the rate at which scientific activity increased was very slow, but over the last three or four decades it has become extremely rapid, so much so that in a country such as the United States the expenditure on research and development now amounts to about 3.5% of the gross national product. In these circumstances science and technology can no longer be cultivated for their own sakes. The money which they demand has been forthcoming from the tax payer because research and development are supposed to contribute to the aims of the society which supports them. In the 1950's and 1960's, there have in fact been only three aims substantially, though there have been many sub-aims. These three aims have been defence, national prestige, and material economic advantage. And it was not until 1969 that the economic objectives of science dominated over the purely military defence objectives. There has of course also been some money spent on objectives such as medical research and so on, but the amounts were relatively trivial. Recent statistics brought out in Paris have tried to rate the importance of some fourteen objectives by reference to recent expenditure on relevant scientific research; the objectives include defence, space, agriculture, industry, nuclear energy, transportation, health, urbanism, environment, and so on. It may interest you to know the relative figures for the efforts of the main countries in the world undertaking scientific research. In terms of the importance of particular objectives within the gross domestic product, i.e., within the national expenditure, industry comes out very high with a comparative figure of 57; agriculture is 9; for the social and service sectors, including health, transportation, education, urban renewal, environment, and so on, the figure is between 0.1 and 0.2. Up till the present, therefore, in the wisdom of governments, the effort devoted to the using of new knowledge for social objectives in contrast to economic objectives, and still more to defence objectives, has been quite trivial. This is all beginning to change, but to change really rather quickly.

Since the main objective at the moment is still economic growth, may I say something about economic growth as such, for which technology and education have been the two major influences. Some fifteen years ago, the growth economists first began to become vocal, and in the United States, for example, Professor Dennison showed that in the growth of the wealth of the United States in this century, only 40% could be ascribed to the classical inputs of manpower and labour, and the rest was due to the so-called residual factor, which in fact is the quality of capital utilisation and the quality of manpower through education, technology, etc. The growth of economy in the

advanced parts of the world in the past two decades has been phenomenal. In the 1960's the main industrialized countries of the world set themselves a target of 50% increase in the gross national product between 1960 and 1970; in fact they achieved a 60% increase. Had Japan been included at the beginning, as it was later, the increase would have been 65%. The aim, which is put forward perhaps a little more sheepishly for the 1970's up to 1980, is a 65% increase. This will probably not be achieved, but is nevertheless the present target. Even so, if it is not quite achieved, compounding the two figures means that the gross prosperity, if you like, of the major countries of the industrialized world will have increased by 150% in 20 years.

Now man has been struggling upwards from subsistence in the face of poverty, disease, and the like for about 2,000 years, and one would expect that this great increase in man's material wealth would be greeted with triumph, as the beginning of the possibility of a golden age in which we have the resources available to attack many of the main ills of mankind and society. When the economic ministers of these countries met last year, they hailed these proposals not with roars of triumph, but with a caveat. Growth must no longer be allowed to be an end in itself. It must be regarded as providing the resources for the development of society, and not for the sake of the resources *per se*. And great attention must be paid to the qualitative aspects of growth, because of the appearance of all the unwanted side effects, not only in environmental pollution but in the nature of cities and in the degradation of the nature of work, and in many other signs of degradation. If one looks at the use to be made of the growth expected in the next decade, it is very interesting that, in terms of the existing policies of these countries, the social demands of populations already would require that all the new resources be spent in achieving social objectives—better education, better transportation, better health care, better cities, and so on; even then the resources would not be sufficient. So there is a tendency as economic affluence rises, for more and more of the resources to be used for social purposes, or for the public to ask for them to be used for such purposes. There is of course good reason for this; at some stage in the growth of human affluence, we shall become saturated with consumer goods. After all, three or four washing machines per family, five or six refrigerators, half-a-dozen television sets and telephones in all the lavatories, such things are enough, and one may want to spend money in other ways. We may even perhaps be seeing the dawn of this saturation, though I am not quite convinced that we are, since man seems to be eternally grasping for material goods. However, it is significant that there is at least enough schizophrenia in the average human being, above a certain level of material prosperity, to want in theory more leisure and better education for the children, even though it may be irrelevant education, or merely keeping up with the Joneses. At least this social pressure exists and it is growing and becoming much more important.

Now I have already hinted at the existence and the importance in all these fields of the bad side effects which have appeared progressively in society in the last few decades. I do not want to describe these in detail, for you know them as well as I do. All the pollution effects, the crowded and unpleasant nature of life in the cities, the sterility of the many faceless suburbs, loss of satisfaction in work, the increasing alienation of individuals from society, the difficulties of increasing crime, drug-taking, delinquency, and all kinds of things which make life perhaps not what many people would want it to be, particularly the kind of facelessness and anonymity, the lack of purpose which this technologically dominated life seems to produce.

I want to talk about the nature of these problems in a general way for a little, because I think they are very important and very little understood. It is all too easy for politicians to take up a subject, such as pollution; it is a nice, popular evil which everyone can fight and which does not really hit back; even industry can be made to do something about it. But to tackle the totality of this cluster of problems, is something which is at the moment almost beyond the wisdom, if such there be, of political leaders and the people who advise them. This mass of problems or "the problematique" as it is called, seems to me to have three main causes.

The first cause is increase in population, essentially in world population, and its ever greater accumulation in the cities. One has it in western Europe, of course, but you see exactly the same thing in the less developed parts of the world, in Calcutta, in Dar-es-Salaam, in Mexico City, in the 'bidonvilles' of Rio de Janeiro.

The second cause of the problematique is the level of affluence. Many new problems appear when people have achieved a level of material prosperity and seem to be released from the constraint of survival of the fittest in its simplest material sense, when they are no longer forced to earn their daily bread, as they did in the past. A further main cause, of course, connected with the other two, is the great, unmanaged upsurge of technology which has been the agent for producing affluence and for concentrating population in cities, and even for providing better food, better nutrition and medical care, and hence encouraging population increase. These three causes, are of course completely interactive and inextricable.

The problematique, or complex of problems I have mentioned again appear to have three features in common. The first feature is that they are global and they seem to appear in any kind of society at a certain level of development irrespective of the social or political system. One has the pollution problems just as much in some parts of the Soviet Union as in capitalist societies—the disappearance of caviar from the Moscow shops, for example, is directly due to the pollution of the Caspian Sea and its falling level, and can hardly be ascribed to capitalism. So there seems then to be a phenomenon of globality in these problems.

The second feature is, as I have already hinted, that they are extremely complex and multi-variant. They have economic, social, political, technological, psychological aspects which are difficult to disentangle. Third, they are enormously interactive. The cluster of inter-related, interacting, inseparable problems appear to be merely symptoms on the surface of society, symptoms of a deep and disseminated malaise. If each is attacked separately the sympton as such may be removed but, in the absence of diagnosis of the nature of the disease there will appear in other parts of the same system further difficulties which will probably not be recognised as being caused by the changes involved in removing the first symptom.

I will now give you three rather brief illustrations slightly caricatured of the interactions within the system. The first one is in connection with DDT, with which I was very closely associated during the War, when it seemed to us to be a miraculously beneficient discovery. We were told afterwards that in the South-East Asian campaign, DDT had prevented three-quarters of a million casualties. There are certainly several million people alive today who would not be alive if DDT had not existed. At the same time, DDT has not yet killed a single person. Yet it is one of those things which is universally attacked as an evil, and probably quite rightly, because long-term effects are not yet well understood. We do not know to what extent it will be bio-degraded in the earth, how much will appear in the seas, how much will accumulate, whether it will exterminate all fish. I know it appears in the eggs of penguins in Antarctica already. It is threatening the existence of the bald-headed eagle, which is regarded as very important, although nature has probably done away with many thousands of species for every one done away with by man.

The DDT problem illustrates the type of interaction and the kind of quandary one is in. One may ask, first of all, was it a good or a bad thing that all these people are alive today who would not have been alive as a result of malaria and many other things, had DDT not existed? They are mainly in the under-developed parts of the world. I would not dare to answer that question though some people might.

Then again, if we in our wisdom feel that a substance like DDT should be banned and its manufacture prohibited in the advanced parts of the world, have we the right, unless we can provide effective substitutes which are harmless, deprive countries like, say, Tanzania with its tse-tse fly and malaria problems, which are basic to its development, of the use of this material? We don't know. To do so would seem just an arbitrary act of neo-colonialism, forbidding the use by poor societies of something which the rich societies can now afford to do without. Ethnically it is extremely difficult to answer any of these questions.

Another example is the so-called Green Revolution. We know very well that the invention of hybrid maize, rice and other crops has made it possible to grow very much more food on the earth, and in many countries food production for starving multitudes is an absolute must. The decision to do so will be made by the Minister of Agriculture, and supported by the aid agencies of the United

Nations and all such bodies. But have we looked enough at the side effects? First of all, because of the intensive use of chemical fertilisers which the green revolution necessitates, it is very likely that all surface water will become polluted within six years in areas where they are used, for example, in India.

Then again, what are the social effects? The intensive growth of many of these new crops as food products requires three crops a year. This cannot be achieved by peasant agriculture; it requires mechanization. This means hundreds of thousands of people flowing into cities like Calcutta, in addition to those who are already doing so today. The provision of employment in most poor countries is also a main national objective, just as is the production of food. The achievement of one aim, solving one problem, tends to aggravate another.

Let us take a case in a developed country: the example of a city such as Los Angeles, where on a huge area in a very fertile plain, a great sprawling city grew. It happened to be near sources of petroleum, it was an ideal place for the development of the automobile. Gradually over the huge area, there were more and more two– and three– car families. Gradually because of the number of people with cars, public transport began to decay and almost to disappear. This entailed of course enormous public expenditure on super highways, on underpasses and all the rest of it, so less and less money was available for public transport. All this car population was encouraged by the city fathers and led to further road building, which was necessary if the cars were to circulate, and of course to be sold. This meant in turn more pollution, more smog. But it also meant that the disappearance of public transport affected the under-privileged part of the population, the Negroes, and the poor; and not only these but also the young and the old, particularly the very young and the very old. The riots at Watts two or three years ago in the United States, took place actually after the Federal Government had provided a considerable number of jobs which were available to Negro workers, but there was no way of them getting to the jobs, to their work-place, from where they lived because there was no transport. It was not thought out as a whole, everything was dealt with separately.

In this great 'problematique' we barely distinguish between symptons and disease, and in attacking the problems, our governmental structures and policies are almost impotent, the structures and policies being in nearly all cases vertical–Ministries of Health, Ministries of Agriculture, Ministries of this, that and the other; the problems are all horizontal. There are actually some very interesting experiments being undertaken on government structures, particularly in Canada at the moment where Mr Trudeau has instituted a completly new system as an experiment, but we do not know yet whether it will work or not.

Beyond all this and in view of the rapidly expanding population of the world as well as of economic growth, still more pressing doubts appear. How near are we in fact to coming right up against the limitations of the planet as such? There has been very little work done on this, though there has been a lot of speculation. For the first time last year a major scientific experiment was started, to try to trace some of the many interactions and the reinforcements brought about by these elements of unrest, uncertainty and change in the world. Plenty of people discuss the increasing world population, but who has discussed the dangers of world population growth in the light of the parallel increases in economic growth and the industrialization necessary to sustain it? And what has been said about the interaction of these two forces of economic and demographic growth on future levels of pollution and on the future demands for the world's raw materials, which are non-renewable? Practically nothing! However, last year an experiment was started, a computerized systems dynamics experiment in America at the Massachussetts Institute of Technology, where six different factors were chosen and related with respect to their longer term trends: world population, world food demands of that population, the agricultural possibilities, the demand on raw materials, levels of economic and industrial performance, and pollution, to see how on a global model all these things would interact and what the results would be. The results are not yet published, but they will be in the early months of 1972. The preliminary results are extremely depressing.

Let us look briefly at the population situation first: in the year 1650, the world population was estimated to be around half a billion souls, and the growth of that population was calculated to be about 0.3% per annum. This of course is an example of organic exponential growth. The doubling of the population at that rate would be a doubling once every 250 years for the world as a whole. So we should have expected about one billion people to be in the world in 1900, 250 years after 1650; by the year 2150, a doubling of that, to two billions, followed by doubling to 4 billions in the year 2,400. This is all far enough off for no one to worry about—4billion people in 2,400. But simple exponential growth was exceeded, largely again thanks to science and technology, to better health and food, and in fact in 1900 the growth rate had left its original 0.3% of 1650, and was already 0.6% per annum, i.e., the world's population in 1900 was doubling at the rate of about once every 115 years. By 1950 the increase in the rate of population growth had risen to 0.9%, doubling in 77 years. By 1970, the rate of the world's population increase had risen to 2.1%, a doubling of the population of the world every 32 years. Now suppose this increase in the rate stops, and we merely have growth at the present rate of 2.1% per annum: this means 7 billion people in the world by the year 2000, 14 billion by the year 2030, 28 billion by the year 2060. That means that a child born today could expect in its lifetime to see at least four people in the world for every one today, and if he lives for long, the number would be six for every one person in the world today. We do not know what the carrying capacity of the world is; there is no easy answer, it is not a black-and-white calculation; it depends what standards we want human beings to have. Certainly we could have a standing-room-only type of existence in theory, with very low standards of everything—i.e. sheer existence. But this would certainly lead to lemming-like catastrophes long before the standing-room-only situation really happened. If the present trends continue—they must not continue—but if they were to continue, all these large numbers of extra people would expect more goods, would require more industry, provide more pollution, use up raw materials more quickly.

Speculation concerning the world's raw material depletion is difficult since the proved reserves of minerals and other non-renewable resources in the world are always increasing, as a result of new discoveries. However, if we take a very plentiful material, say, bauxite, from which aluminium is made, the present static reserve of bauxite, that is the length of time the present reserves would last at the present rates of use, would be 400 years. That sounds reasonable and we could discover other ways and means of extracting aluminium before then. But if we take into account the world increase in both population and economic demand, this comes down already to 75 years. Petroleum reserves are at present 60 years in static use terms. On the exponential curve of population and economic increase, this comes down to 18 years. Of course the reserves will be doubled or trebled or quadrupled, but that merely puts off the difficulty by a few decades. With regard to many other metals and minerals, the situation is still more dubious; one of the most difficult materials, which has been very seldom talked about, is phosphate, which is essential to food production. Here the supplies at the exponential rate of use are only a few decades, and the phosphate, once it is disseminated through agriculture, is almost impossible to reconcentrate.

The M.I.T. experiment which I mentioned brings all these various factors together on the computer for the first time. It predicts, practically irrespective of the maxima and minima one takes for any of these figures, a major world catastrophe for the human race somewhere between 2020 and 2060, according to the data selected. If one keep pollution down and avoids pollution saturation, by assuming that new technologies of a non-polluting type will be produced, the food situation catches up on us. There will certainly be criticisms of these findings; it is after all the first experiment ever done in this field. It will probably require 5, 10, 20 years of refinement, of deepening, of knowing what our material situation in the world really is. But it is already extremely indicative and politically very suggestive. It shows, for instance, that there is no possiblity of the world's material resources providing a generalized material civilization for all men in developed and under-developed countries anything like as high as that of Europe today, to say nothing of the material levels of the United States. Amongst many other criticisms, people will ask whether abundant energy availability will solve the problem through the development of solar power and nuclear fusion, which might make available limitless amounts of energy. Again will it not be possible to get raw materials from rocks, and food from the air and water? Of course, theroetically, yes. But can we do this on the scale necessary within a hundred years? I don't know. Besides, the pollution

problem resulting from extracting minute proportions of metal from enormous quantities of crushed rock will not be easy. Then again, other people may ask whether new raw material discoveries will make everything all right. Others again will say, if you leave it to Nature, Nature will find the cure. Of course Nature will find an equilibrium, but generally this happens by overshoot, by enlarging the population and then that population just dying out. One has seen many biological experiments in which little fish like guppies, for instance, double the population every so may hours for days and days; the population grows and grows, and then one day you are left with two or three fishes and a lot of corpses. Overshoot is biology's way of solving these disequilibria resulting from exponential growth. I do not think we particulary want to leave it at that.

The world model developed at M.I.T. is necessarily highly aggregated and its consequences would not appear uniformly throughout the world. Approach to catastrophy would appear through sporadic events at centres of particular tension in various parts of the world. There would be events triggered off by political tension—war, famine, disease as in Bengal today. Richer nations would seek security in isolation and attempted self-sufficiency but might easily disrupt owing to the cutting off of raw materials and the collapse of the industrial economy. Countries such as Japan, with very high rates of growth, great human energy and absolute lack of raw material resources, would no doubt break out through military adventure. But whatever the specific effect, the prospects would not be very happy.

However the situation is not completely black. Other alternatives for the human race exist. On the purely material plane, those responsible for the M.I.T. experiment have already made preliminary studies, assuming other value systems which give a lower priority to the purely material, to see whether a world equilibrium might not, after all, be attainable which could persist for centuries and give the race more time to develop its own salvation. It does appear that it would be possible for the world to sustain a reasonably high population, a bit higher, perhaps a good deal higher than that of today, but not the astronomical doublings I was talking about a few minutes ago, and to sustain that population at a decent material standard, not as high as today, but a decent standard, a standard high enough to give every possibility of social and individual development. This would require, of course, a major change in human goals and behaviour, and entail enormous political upheavals and policy decisions, extremely difficult to achieve. It would require, for example, industry to be re-geared to producing first of all pollution-free types of manufacture, to providing goods, consumer goods with the longest possible active life, not the shortest possible. It would necessitate the end of the economy of waste; it would need great industries for re-cycling materials, and extracting materials from the sea and from the rocks, more and more, and of course all this would depend upon the existence of a society where the purely material and the purely selfish material motive would not be dominant. Of course, this would entail, as I say, a very quick decision to begin to stop growth of population and growth of economy, extremely difficult politically, because we should be asking the under-developed countries to stop their population growth. They would react fiercely at first in any case, to this apparently neo-colonialist pressure from countries which, having achieved a high degree of affluence, wished selfishly to retain it at the expense of the majority of the world's population. In the advanced countries the vested interests, such as industry and the Trade Unions, devoted to profit and material advantage, would object equally. The ordinary people would not easily accept a reduction of their material standards. Only fear of impending catastrophe is likely to make possible the necessary and revolutionary changes in the values of life.

The M.I.T. projections are not an experiment in futurology; they are trend analyses to indicate what is likely to happen if present growth and present policy persists, in order that their indications shall *not* come to pass. What is sure is that the human species approaches a moment of fundamental crisis. There are ways out, but little time left to initiate the basic changes in human objectives, motivations and behaviour which are necessary if man is to survive.